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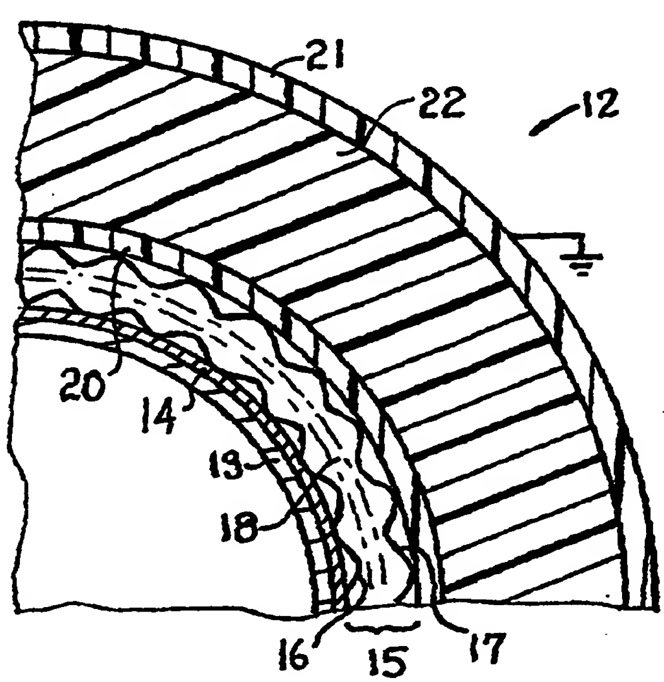
(54) Title: HIGH VOLTAGE INDUCTION DEVICE

(57) Abstract

A high voltage induction device including a power cable (12) comprising inner conducting means (13-15) and outer electrical insulation (20-22) having spaced apart inner and outer layers (20, 21) of semiconducting material and, positioned between the inner and outer layers, and intermediate layer (22) of electrically insulating material. The conducting means comprises conductor means (14) and cooling means (13) for cooling the conductor means (14) to improve the electrical conductivity of the conductor means. The inner layer (20) of semiconducting material is electrically connected to the conductor means and the outer layer (21) of semiconducting material is at a controlled electric potential along its length.



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High Voltage Induction Device

TECHNICAL FIELD

This invention relates to a high voltage induction device having a winding comprising a power cable having cooled conducting means. In particular, but not exclusively, the invention relates to a high voltage induction device having a power cable with conducting means having superconducting properties, for example a high- transition (or critical) temperature superconducting (HTS or high-T_c) cable. The high voltage of the induction device may be up to 400 kV to 800 kV. Examples of such high voltage induction devices are:

- power transformers, particularly superconducting power transformers having rated power outputs ranging from several hundred kVA to in excess of 1000 MVA and rated voltages of from 3-4 kV to very high transmission voltages (400 to 800 kV), in which power transformers the windings are formed from the power cable;
- superconducting magnetic energy storage (SMES) systems in which the power cable is wound into a coil for the storage of energy as magnetic energy.
- motors and generators; and
- fault-current limiters.

BACKGROUND OF THE INVENTION

A known electrically insulated conductor is disclosed in US-A-5,036,165 and comprises inner electrical conducting means and a surrounding electrical insulation comprising inner and outer semiconducting layers of pyrolysed organic material and glass fibre and an intermediate layer of electrically insulating material sandwiched between said inner and outer layers. The specification does not indicate whether the conductor is suitable for power applications and is not intended as a superconducting cable. Furthermore, it is believed that the semiconducting layers are relatively stiff and inflexible so that the conductor cannot easily be flexed at ambient operating temperatures.

In this specification the term "semiconducting material" means a material which has a considerably lower conductivity than an electric conductor but which does not have such a low conductivity that it is an electrical insulator. Suitably, but not exclusively, a semiconducting material should have a volume resistivity of from 1 to 10^5 $\Omega\cdot$cm, preferably from 10 to 500 $\Omega\cdot$cm and most preferably from 10 to 100 $\Omega\cdot$cm, typically about 20 ohm·cm.

Another known electric cable for use as a phase winding of a linear motor is disclosed in US-A-4,785,138. This known cable has a central core of stranded copper and/or aluminium wires, surrounding electrical insulation formed of extruded layers of plastics material comprising an inner layer of semiconducting material, an outer layer of semiconducting material and an intermediate layer of electrically insulating material sandwiched between the inner and outer layers, and a surrounding outer sheathing of good electrical conductivity which provides good shielding in cooperation with the outer layer of semiconducting material. This known cable is not intended as a superconducting power cable .

In US-A-4,785,138 the three layers forming the electrical insulation comprise thermoplastic materials which are extruded together over the central conductive core and the sheathing is applied in a final stage. The inner and outer layers of semiconducting material are made "semiconducting" by the incorporation in the thermoplastics material of electrically conductive particles, such as carbon black or soot.

It is also known to provide superconducting cables with similar electric insulation to that described in US-A-4,785,138. For example a room temperature dielectric design of superconducting cable is described in a paper entitled "Insulation systems for Superconducting Transmission Cables" by Ole Tønnesen presented at the Nordic Insulation Symposium held at Bergen from 10-12 June, 1996. However in this known

superconducting cable a mantle and screen is also applied outside the electrical insulation.

SUMMARY OF THE INVENTION

An aim of the present is to provide a high voltage induction device including a power cable in which, in use, the electric field is confined at least substantially within the electrical insulation and which can be designed to handle very high operating voltages, e.g. up to 800 kV.

It is also an aim of the present invention to provide a high voltage induction device having a cooled power cable, e.g. with superconducting properties, having electrical insulation with an outer layer of semiconducting material at a controlled electrical potential, e.g. earth potential, along its length.

According to the present invention a high voltage induction device including a power cable comprising inner conducting means and outer electrical insulation having spaced apart inner and outer layers of semiconducting material and, positioned between said inner and outer layers, an intermediate layer of electrically insulating material, is characterised in that said conducting means comprises conductor means and cooling means for cooling the conductor means to improve the electrical conductivity of the conductor means, in that the said inner layer is electrically connected to said conductor means, and in that the said outer layer of semiconducting material is at a controlled electric potential along its length.

The semiconducting outer layer is designed to act as a screen to prevent losses caused by induced voltages. Induced voltages could be reduced by increasing the resistance of the outer layer. Since the thickness of the semiconducting layer cannot be reduced below a certain minimum thickness, the resistance can only be reduced by selecting a material for the layer having a higher

resistivity. However, if the resistivity of the semiconducting outer layer is too great the voltage potential between adjacent spaced apart points at a controlled, e.g. earth, potential will become sufficiently high as to risk the occurrence of corona discharge with consequent erosion of the insulating and semiconducting layers. The semiconducting outer layer is therefore a compromise between a conductor having low resistance and high induced voltage losses but which is easily held at a desired controlled electric potential, e.g. earth potential, and an insulator which has high resistance with low induced voltage losses but which is difficult to hold at the controlled electric potential along its length. Thus the resistivity ρ_s of the semiconducting outer layer should be within the range $\rho_{min}<\rho_s<\rho_{max}$, where ρ_{min} is determined by permissible power loss caused by eddy current losses and resistive losses caused by voltages induced by magnetic flux and ρ_{max} is determined by the requirement for no corona or glow discharge.

By holding the semiconducting outer layer at a controlled electric potential, e.g. earth potential, at spaced apart intervals along its length, the outer layer provides a substantially equipotential outer surface and there is no need for an outer metal shield and protective sheath to surround the semiconducting outer layer. The diameter of the cable is thus reduced allowing more turns to be provided for a given size of winding. The inner layer, which is in electrical contact with the conductor means, provides an equipotential inner surface at a different electric potential to the outer equipotential surface. A radial electric field is thus provided between the equipotential surfaces wholly contained within the magnetically permeable electric insulation.

The conductor means preferably comprises superconducting means. In this case the conductor means may comprise low temperature superconductors, but most preferably comprises HTS materials, for example HTS wires or

tape helically wound on an inner tube. A convenient HTS tape comprises silver-sheathed BSCCO-2212 or BSCCO-2223 (where the numerals indicate the number of atoms of each element in the $[Bi, Pb]_2$ Sr_2 Ca_2 Cu_3 O_x molecule) and hereinafter such HTS tapes will be referred to as "BSCCO tape(s)". BSCCO tapes are made by encasing fine filaments of the oxide superconductor in a silver or silver oxide matrix by a powder-in-tube (PIT) draw, roll, sinter and roll process. Alternatively the tapes may be formed by a surface coating process. In either case the oxide is melted and resolidified as a final process step. Other HTS tapes, such as TiBaCaCuO (TBCCO-1223) and YBaCuO (YBCO-123) have been made by various surface coating or surface deposition techniques. Ideally an HTS wire should have a current density beyond $j_c \sim 10^5$ Acm^{-2} at operation temperatures from 65 K, but preferably above 77 K. The filling factor of HTS in the matrix needs to be high so that the engineering current density $j_e \geq 10^4$ Acm^{-2}. j_c should not drastically decrease with applied field within the Tesla range. The helically wound HTS tape is cooled to below the critical temperature T_c of the HTS by a cooling fluid, preferably liquid nitrogen, passing through the inner support tube.

An outer cryostat layer may be arranged around the helically wound HTS tape, to thermally insulate the cooled HTS tape from the electrically insulating material, or around the electrically insulating material. Alternatively, however, the cryostat may be dispensed with. In this latter case, the electrically insulating material may be applied directly over the conducting means. Alternatively thermal expansion means may be provided between the conducting means and the surrounding insulating material. The thermal expansion means may comprise a space, e.g. a void space or a space filled with compressible material, such as a highly compressible foamed material. Such a space reduces expansion/contraction forces on the insulation system during heating from/cooling to cryogenic temperatures. If the space is filled with compressible material, the latter can

be made semiconducting to ensure electrical contact between the semiconducting inner layer and the conducting means.

Other designs of conducting means are possible, the invention being directed to cooled conducting cables (preferably cooled to a temperature which does not exceed 200 K), preferably cooled superconducting cables, of any suitable design having a surrounding electrical insulation of the type described above. The plastics materials of the electrical insulation ensure that the cable can be flexed to a desired shape or form at least when at ambient temperatures. At cryogenic temperatures, the plastics materials are generally rigid. However the cable may be wound into a desired form, e.g. into the shape of a coil, at ambient temperatures before cryogenic cooling fluids are used to cool the conducting means.

The electrical insulation is of substantially unitary construction. The layers of the insulation may be in close mechanical contact but are preferably actually joined together, e.g. by extrusion of radially adjacent layers together.

Conveniently the electrically insulating intermediate layer comprises solid thermoplastics material, such as low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethylpentene (PMP), ethylene (ethyl) acrylate copolymer, cross-linked materials, such as cross-linked polyethylene (XLPE), or rubber insulation, such as ethylene propylene rubber (EPR) or silicone rubber. The semiconducting inner and outer layers may comprise similar material to the intermediate layer but with conducting particles, e.g of carbon black or metal, embedded therein. Generally it has been found that a particular insulating material, such as EPR, has similar mechanical properties when containing no, or some, carbon particles.

BRIEF DESCRIPTION OF THE DRAWING

Embodiments of the invention will now be described, by way of example only, with particular reference to the accompanying drawing, in which:

Figure 1 is a schematic sectional view through part of one embodiment of a power cable of a high voltage induction device according to the invention; and

Figure 2 is a schematic sectional view through part of another embodiment of a power cable of a high voltage induction device according to the invention.

Figure 1 shows a power cable 12 of a high voltage induction device, the power cable comprising an inner metallic tubular support 13, e.g. of copper or a highly resistive metal, such as copper-nickel, alloy, on which is helically wound elongate HTS material, for example BSCCO tape or the like, to form a superconducting layer 14 around the tubular support 13. A cryostat 15, arranged outside the superconducting layer, comprises two spaced apart flexible corrugated metal tubes 16 and 17. The space between the tubes 16 and 17 is maintained under vacuum and contains thermal superinsulation 18. Liquid nitrogen, or other cooling fluid, is passed along the tubular support 13 to cool the surrounding superconducting layer 14 to below its critical superconducting temperature T_c. The tubular support 13, superconducting layer 14 and cryostat 15 together constitute superconducting means of the cable 12.

Electrical insulation is arranged outside the superconducting means. The electrical insulation is of unified form comprising an inner semiconducting layer 20 in electrical contact with the superconducting layer 14, an outer semiconducting layer 21 and, sandwiched between these semiconducting layers, an insulating layer 22. The layers 20-22 preferably comprise thermoplastics materials solidly connected to each other at their interfaces. Conveniently

these thermoplastics materials have similar coefficients of thermal expansion and are preferably extruded together around the inner superconducting means. Preferably the layers 20-22 are extruded together around the inner superconducting means to provide a monolithic structure so as to minimise the risk of cavities and pores within the electrical insulation. The presence of such pores and cavities in the insulation is undesirable since it gives rise to corona discharge in the electrical insulation at high electric field strengths. If the semiconducting layer 20 is in contact with the tube 17, the contacting surfaces should be smooth to cater for thermal movement between the surfaces when changes occur in the thermal gradient between the inside and outside of the cable 12. In an alternative embodiment the cryostat 15 could be positioned outside the electrical insulation.

By way of example only, the solid insulating layer 22 may comprise cross-linked polyethylene (XLPE). Alternatively, however, the solid insulating layer may comprise other cross-linked materials, low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethylpentene (PMP), ethylene (ethyl) acrylate copolymer, or rubber insulation, such as ethylene propylene rubber (EPR), ethylene-propylene-diene monomer (EPDM) or silicone rubber. The semiconducting material of the inner and outer layers 20 and 21 may comprise, for example, a base polymer of the same material as the solid insulating layer 22 and highly electrically conductive particles, e.g. particles of carbon black or metallic particles, embedded in the base polymer. The volume resistivity, typically about 20 ohm·cm, of these semiconducting layers may be adjusted as required by varying the type and proportion of carbon black added to the base polymer. The following gives an example of the way in which resistivity can be varied using different types and quantities of carbon black.

Base Polymer	Carbon Black Type	Carbon Black Quantity (%)	Volume Resistivity Ω·cm
Ethylene vinyl acetate copolymer/ nitrite rubber	EC carbon black	~15	350-400
-"-	P-carbon black	~37	70-10
-"-	Extra conducting carbon black, type I	~35	40-50
-"-	Extra conducting black, type II	~33	30-60
Butyl grafted polyethylene	-"-	~25	7-10
Ethylene butyl acrylate copolymer	Acetylene carbon black	~35	40-50
-"-	P carbon black	~38	5-10
Ethylene propene rubber	Extra conducting carbon black	~35	200-400

The outer semiconductive layer 21 is connected, e.g. at spaced apart regions along its length, to a controlled potential. In most practical applications this controlled potential will be earth or ground potential. The specific spacing apart of adjacent earthing points being dependent on the resistivity of the layer 21.

The semiconducting layer 21 acts as a static shield and as an earthed outer layer which ensures that the electric field of the superconducting cable is retained within the solid insulation between the semiconducting layers 20 and 21 in use of the high voltage induction device. Losses caused by induced voltages in the layer 21 are reduced by increasing the resistance of the layer 21. However, since the layer 21 must be at least of a certain minimum thickness, e.g. no less than 0.8 mm, the resistance can only be increased by selecting the material of the layer to have a relatively high resistivity. The resistivity cannot be increased too much, however, else the voltage of the layer 21 mid-way between two adjacent earthing points will be too high with the associated risk of corona discharges occurring.

Figure 2 shows an alternative design of superconducting cable, generally designated by the reference numeral 30, for a high voltage induction device according to the invention. The cable 30 has an inner metal, e.g. copper or highly resistive metal or alloy, support tube 31 and an HTS wire 32 wound helically around the tube 31 and embedded in a layer 33 of semiconducting plastics material. The semiconducting plastics material of the layer 33 is suitably of the same material as the layers 21 and 22 described with reference to Figure 1. Electrical insulation is arranged outwardly of, at a small radial spacing 34 from, the layer 33. This electrical insulation comprises inner and outer semiconducting layers 35 and 36 and, sandwiched therebetween, an electrically insulating layer 37. These layers 35-37 are formed substantially similarly to, and may be generally of the same composition as, the layers 20-22 of the cable of Figure 1.

The radial spacing 34 provides an expansion/contraction gap to compensate for the differences in the thermal coefficients of expansion (α) between the electrical insulation system and the superconductor assembly (including the metal tube). The spacing 34 may be a void space or may incorporate a foamed, highly compressible material to absorb any relative movement between the superconductor and insulation system. The foamed material, if provided, may be semiconductive to ensure electrical contact between the layers 33 and 35. Additionally or alternatively, metal wires may be provided for ensuring the necessary electrical contact between the layers 33 and 35.

The HTS wire 32 is cooled to cryogenic temperatures by the passage of a cooling fluid, e.g. liquid nitrogen, through the tube 31.

Although the present invention is primarily directed to high voltage induction devices including power cables having conducting means with superconducting properties which are cooled to superconducting temperatures in use, the

invention is also intended to embrace high voltage induction devices with power cables having conducting means which have improved electrical conductivity at a low operating temperature, up to, but preferably no more than, 200 K, but which may not possess superconducting properties at least at the intended low operating temperature. At these higher cryogenic temperatures, liquid carbon dioxide can be used for cooling the conductor means.

The electrical insulation of a power cable of a high voltage induction device according to the invention is intended to be able to handle very high voltages and the consequent electric and thermal loads which may arise at these voltages. By way of example, a high voltage induction device according to the invention may comprise a power transformer having a rated power from a few hundred kVA up to more than 1000 MVA and with a rated voltage ranging from 3-4 kV up to very high transmission voltages of 400-800 kV. At high operating voltages, partial discharges, or PD, constitute a serious problem for known insulation systems. If cavities or pores are present in the insulation, internal corona discharge may arise whereby the insulating material is gradually degraded eventually leading to breakdown of the insulation. The electric load on the electrical insulation of a power cable according to the present invention is reduced by ensuring that the inner layer of the insulation is at substantially the same electric potential as the inner conducting means and the outer layer of the insulation is at a controlled, e.g. earth, potential. Thus the electric field in the intermediate layer of insulating material between the inner and outer layers is distributed substantially uniformly over the thickness of the intermediate layer. Furthermore, by having materials with similar thermal properties and with few defects in the layers of the insulating material, the possibility of PD is reduced at a given operating voltages. The power cable of a high voltage induction device can thus be designed to withstand very high operating voltages, typically up to 800 kV or higher.

Although it is preferred that the electrical insulation should be extruded in position, it is possible to build up an electrical insulation system from tightly wound, overlapping layers of film or sheet-like material. Both the semiconducting layers and the electrically insulating layer can be formed in this manner. An insulation system can be made of an all-synthetic film with inner and outer semiconducting layers or portions made of polymeric thin film of, for example, PP, PET, LDPE or HDPE with embedded conducting particles, such as carbon black or metallic particles and with an insulating layer or portion between the semiconducting layers or portions.

For the lapped concept a sufficiently thin film will have butt gaps smaller than the so-called Paschen minima, thus rendering liquid impregnation unnecessary. A dry, wound multilayer thin film insulation has also good thermal properties and can be combined with a superconducting pipe as an electric conductor and have coolant, such as liquid nitrogen, pumped through the pipe.

Another example of an electrical insulation system is similar to a conventional cellulose based cable, where a thin cellulose based or synthetic paper or non-woven material is lap wound around a conductor. In this case the semiconducting layers, on either side of an insulating layer, can be made of cellulose paper or non-woven material made from fibres of insulating material and with conducting particles embedded. The insulating layer can be made from the same base material or another material can be used.

Another example of an insulation system is obtained by combining film and fibrous insulating material, either as a laminate or as co-lapped. An example of this insulation system is the commercially available so-called paper polypropylene laminate, PPLP, but several other combinations of film and fibrous parts are possible. In these systems various impregnations such as mineral oil or liquid nitrogen can be used.

CLAIMS

1. A high voltage induction device including a power cable (12) comprising inner conducting means (13-15) and outer electrical insulation (20-22) having spaced apart inner and outer layers (20, 21) of semiconducting material and, positioned between the inner and outer layers, an intermediate layer (22) of electrically insulating material, characterised in that said conducting means comprises conductor means (14) and cooling means (13) for cooling the conductor means (14) to improve the electrical conductivity of the conductor means, in that the said inner layer (20) is electrically connected to said conductor means, and in that the said outer layer (21) of semiconducting material is at a controlled electric potential along its length.

2. An induction device according to claim 1, characterised in that the said outer layer (21) has a resistivity of from 1 to 10^5 ohm·cm.

3. An induction device according to claim 1, characterised in that the said outer layer (21) has a resistivity of from 10 to 500 ohm·cm, preferably from 10 to 100 ohm·cm.

4. An induction device according to any one of claims 1 to 3, characterised in that the resistance per axial unit length of the semiconducting outer layer (21) is from 5 to 50,000 $ohm.m^{-1}$.

5. An induction device according to any one of claims 1 to 3, characterised in that the resistance per axial unit of length of the semiconducting outer layer (21) is from 500 to 25,000 $ohm.m^{-1}$, preferably from 2,500 to 5,000 $ohm.m^{-1}$.

6. An induction device according to any one of the preceding claims, characterised in that the semiconducting outer layer (21) is contacted by contact means at said

controlled electric potential at spaced apart regions along its length, adjacent contact regions being sufficiently close together that the voltages of mid-points between adjacent contact regions are insufficient for corona discharges to occur within the electrically insulating means.

7. An induction device according to any one of the preceding claims, characterised in that said controlled electric potential is at or close to ground potential.

8. An induction device according to any one of the preceding claims, characterised in that the said intermediate layer (22) is in close mechanical contact with each of said inner and outer layers (20 and 21).

9. An induction device according to any one of claims 1 to 7, characterised in that the said intermediate layer (22) is joined to each of said inner and outer layers (20 and 21).

10. An induction device according to claim 9, characterised in that the strength of the adhesion between the said intermediate layer (22) and each of the semiconducting inner and outer layers (20, 21) is of the same order of magnitude as the intrinsic strength of the material of the intermediate layer.

11. An induction device according to claim 9 or 10, characterised in that the said layers (20-22) are joined together by extrusion.

12. An induction device according to claim 11, characterised in that the inner and outer layers (20,21) of semiconducting material and the insulating intermediate layer (22) are of plastics material and are applied together over the conducting means through a multi layer extrusion die.

13. An induction device according to any one of the preceding claims, characterised in that said inner layer (20) comprises a first plastics material having first electrically conductive particles dispersed therein, said outer layer (21) comprises a second plastics material having second electrically conductive particles dispersed therein, and said intermediate layer (22) comprises a third plastics material.

14. An induction device according to claim 13, characterised in that each of said first, second and third plastics materials comprises an ethylene butyl acrylate copolymer rubber, an ethylene-propylene-diene monomer rubber (EPDM), an ethylene-propylene copolymer rubber (EPR), LDPE, HDPE, PP, XLPE, EPR or silicone rubber.

15. An induction device according to claim 13 or 14, characterised in that said first, second and third plastics materials have at least substantially the same coefficients of thermal expansion.

16. An induction device according to claim 13, 14 or 15, characterised in that said first, second and third plastics materials are the same material.

17. An induction device according to any one of the preceding claims, characterised in that the conductor means comprises superconducting means.

18. An induction device according to claim 17, characterised in that said superconducting means comprises HTS material.

19. An induction device according to claim 18, characterised in that the HTS material comprises helically wound HTS tapes or conductors.

20. An induction device according to claim 19, characterised in that said cooling means (13) comprises a

support tube on which the HTS material is helically wound and through which, in use, cooling fluid, e.g. liquid nitrogen, is passed to cool the HTS tape below its critical temperature.

21. An induction device according to any one of the preceding claims, characterised in that the conducting means includes an outer cryostat layer (15) for thermally insulating one or more inner layers of said conductor means.

22. An induction device according to claim 21, characterised in that said outer cryostat layer (15) is positioned between said inner conducting means and said outer electrical insulation.

23. An induction device according to claim 21, characterised in that said outer cryostat layer (15) is positioned outside said electrical insulation.

24. An induction device according to any one of the preceding claims, characterised in that thermal expansion means (34) are provided between the inner conducting means (32) and the inner layer (35) of semiconducting material.

25. An induction device according to claim 24, characterised in that said thermal expansion means comprises an expansion gap (34).

26. An induction device according to claim 25, characterised in that the expansion gap (34) comprises a void space.

27. An induction device according to claim 25, characterised in that the expansion gap (34) is filled with compressible material, e.g. foamed plastics material.

28. An induction device according to claim 27, characterised in that the said compressible material includes electrically conductive or semiconductive material.

29. An induction device including a power cable (12) comprising inner conducting means (13-15) having conductor means and cooling means for cooling the conductor means to improve the electrical conductivity of the latter, and outer electrical insulation (20-22) surrounding the conducting means (13-15), characterised in that the electrical insulation includes radially spaced apart inner and outer annular portions (20, 21) which are at least partly electrically conductive, the inner annular portion (20) being electrically connected to said conductor means and the outer annular portion being at a controlled potential, and in that in use, when current passes along the conductor means, the electric field generated is a substantially radial electric field between said inner and outer annular portions.

30. An induction device according to any one of the preceding claims, characterised in that the said outer electrical insulation is designed for high voltage, suitably in excess of 10 kV, in particular in excess of 36 kV, and preferably more than 72.5 kV up to very high transmission voltages, such as 400 kV to 800 kV or higher.

31. An induction device according to any one of the preceding claims, characterised in that the said outer electrical insulation is designed for a power range in excess of 0.5 MVA, preferably in excess of 30 MVA and up to 1000 MVA.

FIG. 2

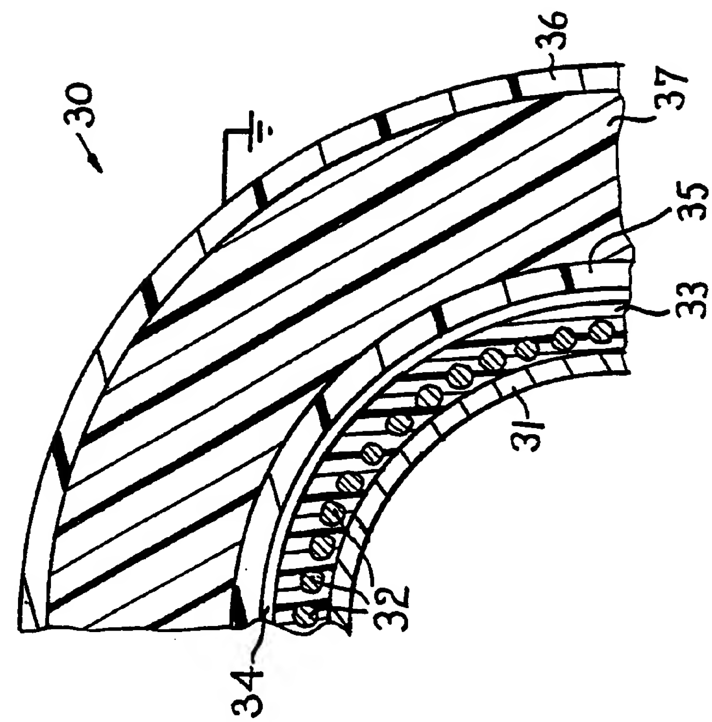
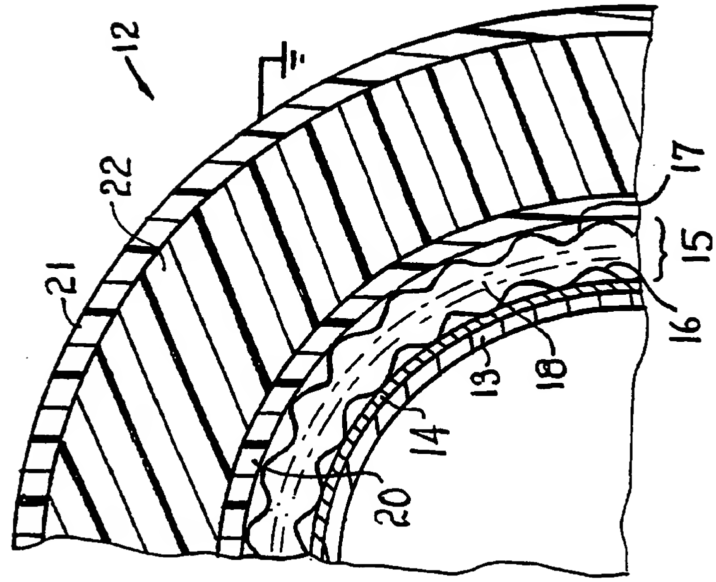


FIG. 1



INTERNATIONAL SEARCH REPORT

Int tional Application No
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A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01F H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 40 22 476 A (THYSSEN INDUSTRIE) 16 January 1992	1
A	see column 1, line 31 - line 36	6-9,11, 13,14, 29,30
	see column 3, line 11 - column 4, line 53; figures 1-3	
Y	GB 2 140 195 A (ELECTRIC POWER RESEARCH INSTITUTE) 21 November 1984	1
A	see page 1, line 108 - page 2, line 107; figures 1-4	8,9,11, 13,14, 17, 20-22, 24,25, 27-30

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 April 1999	19/04/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Demolder, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/07739

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4022476 A	16-01-1992	NONE	
GB 2140195 A	21-11-1984	NONE	